APPENDIX I:

n-p-d-gamma

LH2 TARGET PROPOSED DESIGN PARAMETERS AND SAFETY FEATURES

In order to give our discussions of the design and safety of the target a place to start, I propose the following design parameters and safety features, based on revision of the proposal of 4-23-99.

REQUIREMENTS --

1. Target has to be safe to operate in any conditions and it has to handle any abnormal conditions.
2. Target has to meet any laboratory safety requirements
3. Entry to the experimental cave is required when the target is full.
4. For physics;
   - only nn% neutrons can be lost in the entry walls.
   - only mm% gamma rays from neutron capture on proton can be lost on the walls.

   (nn% and mm% will be given latter – it will be results of Monte Carlo calculations)

GIVEN --

LH2 FLASK

1. 30 cm diam. x 30 cm long
2. Volume: 20 liters
3. Material: Low alloy aluminum (i.e. 6061); and irconium alloys are under consideration Since zirconium requires an understanding of welding and fabrication properties, aluminum is preferred.
4. OK to have dished ends (concave)
5. Thin windows not needed because beam is low energy neutrons
6. Lithium liner to absorb stray neutrons is best inside the flask from physics considerations, but could be outside.
7. LH2 in target region needs to be sub-cooled to minimize bubbles and maximize para- fraction. Normal operating pressure (the pressure of the gas phase) is *proposed* to be 20 psia, so the liquid at the liquid/gas interface will be saturated at this pressure. The target region will be cooled about 3K below this interface temperature.

DETECTORS

Have to cover as much solid angle as possible. The detectors together with electronics (50 detectors and electronic channels) are expensive, therefore, need to be close to the target to minimize costs. Thus, small distance between flask walls and detector crystals is desirable. At present, the space available inside the detectors limits the maximum diameter of the hydrogen target.

EXPERIMENTAL CAVE

1. Walls and roof will be a combination of steel and poly and most probably boronated wax. There should be no cave design before MCNP[Monte Carlo Neutron Physics) shielding calculations are performed. The total thickness of the walls will be about 12-16 inch. “Neutron gas” inside the cave makes even small penetrations in the cave walls difficult to shield.
2. Dimensions inside approx. 4m x 5m x3m high = 60 cu. meters
3. Need personnel access while target is running.
4. Will have energized electrical devices inside with hydrogen ignition potential.

PROPOSED –

LH2 FLASK

1. Normal operating pressure (pressure controller set point): 20 psia (9 psi *gauge* in Los Alamos, where local atmosphere pressure = 580 mm Hg (11.2 psi))
2. Low pressure alarm set point: 18 psia
3. High pressure alarm: 22 psia
4. Relief valve set (cracking) point: 25 psia (10 psi delta at sea level, 14 psi delta in Los Alamos)
5. Relief valve flow capacity: Appropriate for maximum credible accident (filling of insulating vacuum space with helium from the helium jacket) giving greatest H2 boiloff rate.
6. Rupture disk breaking pressure: 27.5 psia
7. Relief paths: 2 independent paths, each capable of handling full flow from maximum credible accident.
8. Vent discharge: Outside building.
9. Design pressure -- Internal: 4 x [relief device set pressure (psia)]
   Safety factor for vent line pressure drop calculation uncertainty = 2.
   Safety factor for general comfort = 2.
10. Design Pressure – External: {[Vacuum relief valve set pressure plus pressure drop developed through line between vac. vessel and relief valve during maximum credible accident (probably total rupture of LN2 precooler while flask is evacuated)] x 4} or 15 psi, whichever is larger.
11. Design Standards: ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2; ASME B31.3 Code for Pressure Piping – Process Piping; CGA S-1.3 Pressure Relief Device Standards – Part 3 – Stationary Storage Containers for Compressed Gases.

INSULATING VACUUM VESSEL

1. Relief valve set (cracking) pressure: 2 psig
2. Relief valve flow capacity.
3. Vent discharge: Outside building
4. Design Pressure – Internal: 4 x [relief device set pressure (psia)] or 100 psi, whichever is larger.
   Safety factor for vent line pressure drop calculation uncertainty = 2.
   Safety factor for general comfort = 2.
5. Design Pressure – External: 10 psig (25 psia) while vessel is evacuated.
6. Design Standards: ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 ASME B31.3 Code for Pressure Piping – Process Piping; CGA S-1.3 Pressure Relief Device Standards – Part 3 – Stationary Storage Containers for Compressed Gases.

HELIUM JACKET

1. Construction: Metal, high vacuum tight.
2. Relief valve set (cracking) pressure: 5 psig
3. Relief valve flow capacity.
4. Vent discharge: Outside building
5. Design Pressure – Internal: 30 psig.
6. Design Pressure – External: 15 psia (to allow for evacuating for leak checking).
7. Design Standards: ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2; ASME B31.3 Code for Pressure Piping – Process Piping; CGA S-1.3 Pressure Relief Device Standards – Part 3 – Stationary Storage Containers for Compressed Gases.

TARGET SYSTEM TESTS

1. Components first pressure tested with H2O. Maximum pressure has to be defined.
2. The final test of the system with liquid hydrogen in a safe location and obeying safety rules.
3. LH2 vessel: Instrument H2 vessel with pressure transducers and recorders. Test by filling with LH2 at normal operating pressure, then opening a large valve in the vacuum vessel to either air or helium.
4. Vacuum vessel: Instrument vacuum vessel with pressure transducers and recorders. Replace aluminum LH2 target vessel with similar size one that has a thin Mylar end window. Fill with

LH2 at normal operating pressure. Then rupture the Mylar window by overpressure or a motorized knife, etc.

CAVE EXHAUST

1. As needed for personnel comfort. This air flow is not a primary part of the hydrogen safety system since the hydrogen is considered to be adequately contained by the robust hydrogen flask, vacuum vessel, and helium jacket.
2. Exhaust port located near ceiling of cave in location for best neutron shielding.
3. Ventilation rate: Two-speed fan (200 cfm) all the time and on detection of gas increase to 800 cfm which changes volume in approximately 2 minutes.
4. Fan motor either explosion-proof or mounted outside air stream. Rotor to be non-sparking construction.
5. Exhaust ducted outside building

EMERGENCY HYDROGEN DISPOSAL

In a case of fire or some other reason it must be possible to dispose of the hydrogen inventory quickly. Proposed: have a small tank of helium connected to the vacuum vessel through an electrically controlled valve and sized to spoil the insulating vacuum by ~1 Torr.

CAVE ELECTRICAL EQUIPMENT

OK to use ordinary equipment – do not need explosion-proof or the like. Argument: The robust design of the flask and vacuum jacket plus the addition of the helium jacket makes release of hydrogen into the cave extremely unlikely.

WARNINGS, ALARMS AND INTERLOCKS

1. Definitions:
   a. Normal: The system operating as designed with all interlocks and sensors active and within set ranges.
   b. Warning: Some sensor(s) are at values between low and high trip points. Local indication (horn, lights, signs) and possibly phone dialer initiated. Operator attention is required but automatic shutdown action is not needed. Necessary personnel may be near the equipment with caution; others should stay away.
   c. Alarm: Some sensor(s) have exceeded their high trip levels. Automatic safety and/or shutdown systems take over. Local indications (horns, lights, signs). All personnel should leave the area. Neutron beam in experiment flight path shut off. CCR automatically notified. Phone dialer initiated.

Sensor	**Location**	**Trip point**	**Action**
H2 concentration#1 H2 concentration #2	Cave, in stagnant air near ceiling	10% of LEL	Warning
H2 concentration #1 H2 concentration #2	Cave, in stagnant air near ceiling	25% of LEL	Alarm. H2 System shutdown and rapid H2 dump. Electrical power in cave shut off.
Air flow	Cave exhaust	70% of normal flow	Warning
H2 concentration	Helium jacket	> Low	Warning
H2 concentration	Helium jacket	> High	Alarm. H2 System shutdown and rapid H2 dump.
Vacuum (pressure) sensor	Vacuum jacket	Bad	Warning

H2 concentration	Vacuum jacket	Low	Warning
H2 concentration	Vacuum jacket	High	Alarm. H2 System shutdown and rapid H2 dump.
RGA	Vacuum jacket	He peak > Low	Warning
RGA	Vacuum jacket	He peak > High	Alarm. H2 System shutdown and rapid H2 dump.
RGA	Vacuum jacket	N2 peak > Low	Warning
RGA	Vacuum jacket	H2O peak > Low	Warning
H2 pressure	Target gas	0 < P < 2 psig	Warning
H2 pressure	Target gas	4 < P < 6 psig	Warning
O2 concentration #1 O2 concentration #2	Cave, at normal breathing space elevation	Low	Warning